Sorghum Grain and Forage Yield Improvement in the Sonoran Desert by Use of Municipal Wastewater[1]

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Abstract

Experiments were conducted near Buckeye, Arizona in 1975 and 1976 to study the influence of treated municipal wastewater on growth and yield of sorghum *(Sorghum bicolor* (L.) Moench*)*. Pump water from local wells (control treatment) and a 50:50 mixture of wastewater and pump water were the two sources of irrigation water used. Sorghum irrigated with the wastewater-pump water mixture grew taller and produced more heads per unit area than did sorghum irrigated with pump water alone in 1975 and 1976. Grain yields and forage yields were also higher for sorghum irrigated with the wastewater-pump water mixture than they were for sorghum irrigated with pump water alone, in both years. Grain volume-weight was not adversely affected by irrigating with the wastewater-pump water mixture. *Additional Index Words:* Cereal grains, Silage, Irrigation, Sewage effluent, and Environmental pollution.

Introduction

Buckeye, Arizona, an agricultural community located about 48 km (30 mi) west of Phoenix in central Arizona, consists of about 7,290 ha (18,000 acres) of farmland. The well water in this district is high in total soluble salts. When the well water is used as the only source of irrigation water, maximum potential yields may not be reached for some crops. To dilute the salt concentration of the well water, the Buckeye Irrigation Company began blending treated municipal wastewater from the city of Phoenix with well water in 1962. The amount of wastewater used for irrigation has increased steadily since that date.

Literature Review

Treated municipal wastewater can be used as a partial source of irrigation water and plant nutrients in the commercial production of cereal grains. Day et al. (1962) reported higher grain yields from cereal grains irrigated with wastewater than from cereal grains irrigated with pump water and no additional fertilizer. Wastewater-nitrogen and fertilizer-nitrogen were equally effective in stimulating forage production (Bole and Bell, 1978). Dye (1958) noted that sewage effluent from an activated sludge treatment plant contained more nitrogen (N), phosphorus (P), and potassium (K), the principal elements for plant growth, than irrigation water from wells. According to Day et al. (1972), irrigation with wastewater over extended periods did not decrease field crop yields or result in any major deleterious effects on agricultural soils. Wheat *(Triticum aestivum* L.*)* grain grown with wastewater contained more protein than when produced with well water and equivalent amounts of N, P, and K(Day et al, 1975).

Sorghum *(Sorghum bicolor* L.*)* grown with wastewater produced higher grain yields than with well water plus N, P, and K in amounts equal to those present in wastewater (Day and Tucker, 1977). Grain sorghum residue consisting of the stalks and unharvested grain from lodged sorghum, is an inexpensive source of cattle feed during the fall and winter months (Ward et al., 1979). The amount of residue that sorghum will yield depends on the genotype, location, year, and farming practices. The nutritional quality of sorghum residue changes with each crop and with the length of time since the last harvest (Perry et al., 1973). Miller et al. (1964)

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Table 1: Average depth of penetration, total soluble salts, nitrate-nitrogen, total nitrogen, and phosphorus for pump water and wastewater and pump water used to irrigate sorghum near Buckeye, Arizona in 1975 and 1976 (2-year average).

Irrigation treatment	Penetration of irrigation water	Total soluble salts	Nitrate nitrogen	Total nitrogen	Phosphorus
	(cm)	(ppm)	(ppm)	(ppm)	(ppm)
Pump water	114 a+	3,654 a	16.2 a	16.2 b	0.0 b
Wastewater and pump water	115 a	1,910 b	8.1 b	30.1 a	3.7 a

+ Means in the same column, followed by the same letter, are not different at the 5% level of significance using the Student-Newman-Keuls' Test.

Table 2: Average plant height, heads per 10 m of row, grain yield, grain volume-weight, and forage yield for sorghum grown with two irrigation treatments near Buckeye, Arizona in 1975 and 1976.

Irrigation treatment	Year	Plant height	Heads/m of row	Grain yield	Grain volume-weight	Forage yield
		(cm)	(no.)	(kg/ha)	(kg/hl)	(metric t/ha)
Pump water (control)	1975	96 b+	41 b	4,032 b	74 a	50 b
	1976	108 b	51 b	4,928 b	72 a	62 b
	1975-76 average	102 b	46 b	4,480 b	73 a	56 b
Wastewater & pump water	1975	116 a	58 a	4,636 a	75 a	61 a
	1976	138 a	70 a	5,668 a	71 a	73 a
	1975-76 average	127 a	64 a	5,152 a	73 a	67 a

+ Means in the same column, for the same year, followed by the same letter, are not different at the 5% level of significance using the Student-Newman-Keuls' Test.

reported that the protein content of sorghum residue may differ because of climate, soil, cultural practices, and variety. According to Perry and Olson (1975), the percentage of crude protein in grain sorghum residues would meet the minimum beef cow requirements, particularly since the animal would selectively graze the most nutritious plant parts.

The objectives of the research reported in this paper were: (1) to study the use of municipal wastewater as a source of irrigation water and plant nutrients in the commercial production of sorghum grain and forage and (2) to study the influence of municipal wastewater on sorghum grain volume-weight.

Materials and Methods

Fields of sorghum grown on similar soil types and under similar management practices were selected to study the effects of municipal wastewater on the yield of sorghum grain and forage near Buckeye, Arizona in 1975 and 1976. The principal soil type was a Gilman loam. The Gilman series is a member of the coarse-loamy, mixed, (calcareous) hyperthermic family of Typic Torrifluvents. The response of sorghum to two sources of irrigation water: (1) pump water alone (control) and (2) municipal wastewater plus pump water in a 50:50 mixture were compared by sampling the selected fields each year. The pump water contained approximately 3,654, 16.2, 16.2, and 0.0 ppm of total soluble salts, nitrate nitrogen, total nitrogen, and phosphorus, respectively. The wastewater-pump water mixture contained approximately 1,910, 8.1, 30.1, and 3.7 ppm of total soluble salts, nitrate nitrogen, total nitrogen, and elemental phosphorus, respectively. Approximately 91 cm (36 inches) of irrigation water were used to produce the sorghum crops. Conventional culture for growing sorghum on 96.5 cm (38-inch) beds, one row per bed, with 7.6 cm (3 inches) between plants in the row was used. The crop was planted during the first week of May each year at a seeding rate of 13.4 kg/ha (12 lb/acre). One hundred and twenty-nine kg/ha (115 lb/acre) of nitrogen were applied before planting to the sorghum that was irrigated with pump water. This amount of nitrogen is equivalent to the amount of nitrogen present in the municipal wastewater mixture. No nitrogen was applied to the sorghum that was irrigated with the wastewater-pump water mixture. All other cultural practices were similar for sorghum grown under the two irrigation treatments. Sorghum was harvested for forage at the hard-dough stage of seed development, which normally occurs about 30 days after 50% flowering.

The following data were obtained from the sorghum crops each year: (1) plant height, (2) heads per meter of row, (3) grain yield, (4) grain volume-weight, and (5) forage yield. The individual plot size for grain yield was 18.2 m (60 ft) of row. The individual plot size for forage yield was 7.7 m (25 ft) of row. The experimental design was a Modified Randomized Complete Block with four replications. The design was modified to take advantage of fields of similar soil types under similar management practices. The standard analysis of variance was applied to all data and treatment means were compared using the Student-Newman-Keuls' Test as described by Little and Hills (1972).

Results and Discussion

Average water penetrations were similar for the two types of irrigation water (Table 1). Total soluble salts and nitrate nitrogen were higher in the pump water than in the wastewater-pump water mixture (Table 1). The wastewater-pump water mixture contained higher levels of total nitrogen and phosphorus than did pump water alone.

The quality of irrigation water is influenced by salt concentrations. The higher the salt concentrations, the lower the quality of the irrigation water and vice versa. The lower concentrations of salts present in the wastewater-pump water mixture indicate that this irrigation water was of a higher quality than pump water and, therefore, more desirable for growing plants. Excessive salt levels in irrigation water may be detrimental to plant growth. Salts inhibit germination, limit water uptake, and may cause specific toxic effects on plants by ions present in the salts (Bernstein et al., 1955).

In 1975 and 1976, plants irrigated with the wastewater-pump water mixture grew taller, produced more heads per unit area, and produced higher grain yields than plants grown with pump water alone. Sorghum grain volume-weight was the same for both irrigation treatments in both years (Table 2). Sorghum irrigated with the wastewater-pump water mixture produced higher forage yields than did sorghum grown with pump water alone in both years (Table 2). Taller plants and higher yields of both grain and forage were obtained when the wastewater-pump water mixture was used for irrigating sorghum, indicating that municipal wastewater can be used effectively as a partial source of irrigation water and plant nutrients in the commercial production of sorghum in Arizona and also in similar environments throughout the world. The irrigation of field crops with wastewater utilizes a municipal waste material effectively and also makes more conventional pump water available for domestic purposes.

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Editorial Note on the Following Article

The Boyce Thompson Southwestern Arboretum lies on the northern flank of Picketpost Mountain in Pinal County, Arizona. The present article is a brief summary relating some of the facts gathered about the mountain. A second article upcoming in Desert Plants deals with vegetational changes in the Picketpost region, particularly in the fenced experimental reserve. It will be of interest to persons interested in revegetation, overgrazing, woodcutting, climatic trends and land management.

William Boyce Thompson's plan for the Arboretum was to develop the land adjacent to Queen Creek and Silver King Wash as cultivated gardens of trees, shrubs, cacti and other plants, but to fence off Arnett Canyon and the north-facing slope of Picketpost Mountain in an experimental attempt to restore and study the natural vegetation which had fared poorly from years of wood-cutting by man and grazing by cattle. Thompson consulted with the U.S. Forest Service prior to developing the Arboretum. On advice of the District Ranger, he purchased patented land on Queen Creek and patented land near Flagstaff in northern Arizona. The northern land, having a fine stand of Ponderosa Pine desired by the government, was traded to the Forest Service for a large tract of land surrounding the Queen Creek acreage. Then an experimental scientific use permit on the entire north-facing slope of Picketpost Mountain was granted Thompson's Arboretum. The Arboretum fenced this experimental reserve in 1929 and the University of Arizona re-fenced it in 1965 on behalf of the Arboretum after signing an agreement to operate the facility. The experimental reserve has been used for scientific studies for 55 years.